7B.3 REGIONAL CLIMATOLOGY AND SURFACE RADIATION BUDGET

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1. INTRODUCTION

The climatology and surface radiation budget (SRB) of a region are intimately related. This paper presents a brief examination of this relationship. An 8-year surface radiation budget data set has been developed based on satellite measurements (Gupta et al., 1999). In that data set and in this paper a region is defined as a quasi-square 2.5° in latitude and approximately the same physical distance in longitude.

A pilot study by Wilber et al. (1998) showed a variety of behaviors of the annual cycles for selected regions. For example, Fig. 1 shows the annual cycle of net longwave (NLW) versus (NSW) flux for a few regions. Selected desert regions form a loop in a specific part of the plot, with large NLW and large NSW. Tropical wet regions form much smaller loops in a different part of the plot, with small NLW and large NSW. For regions selected in high latitude the annual cycles form nearly linear figures in another part of the plot. The question arises as to whether these trajectories are characteristic of the climatology of the region or simply the behavior of the few regions selected from the set of 6596 regions. In order to address this question, it is necessary to classify the climatology of the each region, e.g. as classified by Koeppen (1936) or Trenwarthe and Horne (1980). This paper presents a method of classifying climate of the regions on the basis of the surface radiation behavior such that the results are very similar to the classification of Trenwarthe and Horne. The characteristics of the annual cycle of SRB components can then be investigated further, based on the climate classification of each region.

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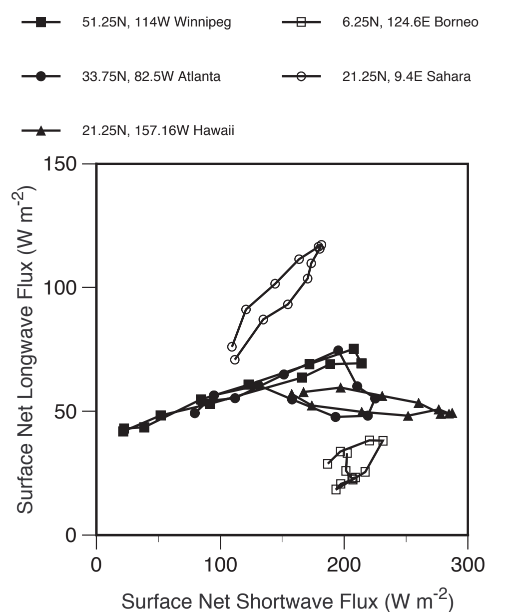

Figure 1. Annual trajectory of net longwave and net shortwave fluxes at surface for selected regions.

2. CLIMATE CLASSIFICATION

Table 1 lists the climate classes of Trenwarthe and Horne for land surfaces. In order to classify the climate of each region, a set of algorithms was evolved, based on the behavior of the annual cycle. Maps of various parameters which describe various features of the annual cycle were examined and criteria were evolved. These criteria are in fact more simple than our initial expectations, but are not considered to be unique.

Table 1. Land climate classification by Trenwarthe and Horne.

A. Tropical:
- Tropical wet (Rain forest)
- Tropical wet and dry (Savanna)

B. Dry:
- Desert
- Steppe

C. Subtropical
D. Temperate
E. Boreal
F. Polar:
- Ice cap
- Tundra

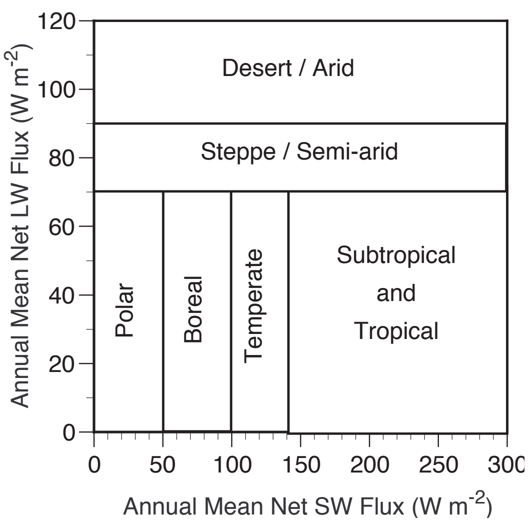

Figure 2. Climate classification of land regions by annual mean net shortwave and longwave fluxes at surface.

Figure 2 shows graphically the criteria which evolved for classification of land regions. The axes of Fig. 2 are similar to Fig. 1 except they are annual mean quantities rather than monthly means. A map of annual mean net longwave surface flux shows that for desert regions, the mean annual net longwave flux (MNLW) at the surface exceeds 90 W m^{-2}. For steppe, the MNLW exceeds 70 W m^{-2} but is less than 90 W m^{-2}. Other land regions have MNLW less than 70 W m^{-2}. For these regions, a map of mean annual net shortwave radiative flux (MNSW) at the surface shows that as one goes from polar through boreal and temperate to subtropical and tropical regions, the climatological types are delineated by appropriate values of MNSW as shown in Fig. 2. The lines between the climatological types are close to latitudinal, but vary due to cloud cover.

Distinguishing tropical and subtropical regions requires additional information. Figure 3 shows the difference between the tropical and subtropical regions, which are distinguished by the annual range of net shortwave flux (RNSW). In the Subtropics, the RNSW is greater than 100 W m^{-2} but in the Tropics the range is less. Within the Tropics the wet regions have an annual mean net longwave flux (MNLW) less than 50 W m^{-2}, because the cloud cover and high humidity are present all year. The tropical wet and dry regions are marked by periods of dry weather broken by an annual or semiannual monsoon, so that the weather changes from desert-like to that of a rain forest. This change is accompanied by a large change in MNLW from that of a desert to that of a rain forest, so that the MNLW is greater than 50 W m^{-2} for the wet-dry regions (savanna).

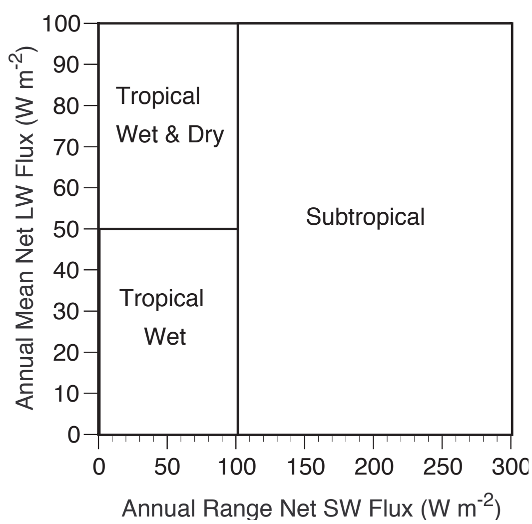

Figure 3. Distinction of tropical and subtropical regions by annual range of net shortwave flux and annual mean longwave flux at surface.

Figure 4 shows that the climatological class for oceans is determined by MNSW for polar and temperate ocean regions. As with land, another descriptor is required to discriminate between tropical and subtropical regions. For ocean, the RNSW is less than 140 W m^{-2} for tropical and greater than 140 W m^{-2} for subtropical oceanic regions.

Climate classification schemes are typically land oriented and do not usually include the Intertropical Convergence Zones and Southwest Pacific Convergence Zone, which are prominent in radiation maps. These regions appear as tropical but with MNSW as less than 210 W m^{-2}.

Application of these criteria to the annual cycle of each region produces the climate classification map shown in Fig. 5. This map compares well with the climate classification map of Trenwarthe and Horne.

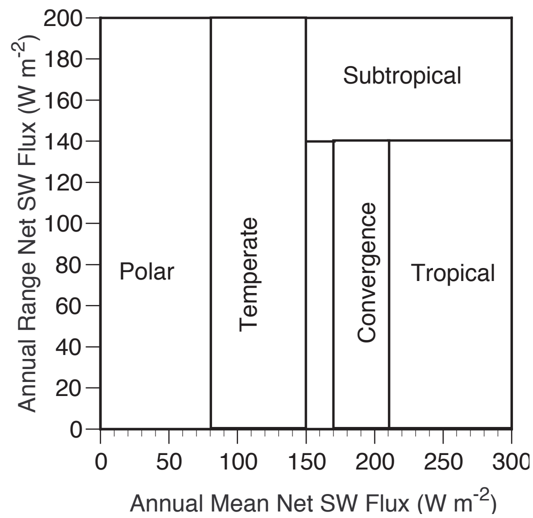

Figure 4. Climate classification of ocean regions by annual mean shortwave flux and annual range of shortwave flux at surface.

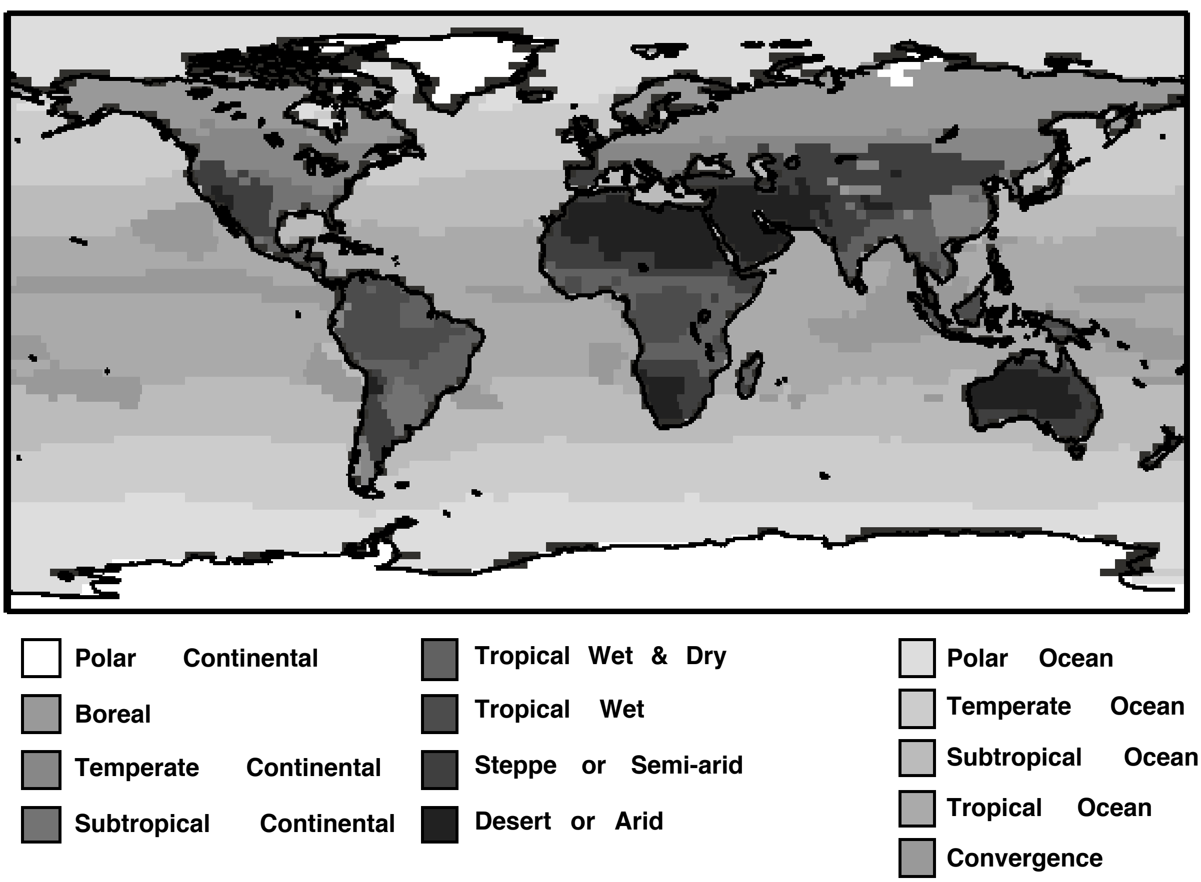

Figure 5. Climate classification map based on surface radiation budget parameters.

3. DISCUSSION.

These algorithms demonstrate that the trajectory of the annual cycle of the NLW and NSW is characteristic of climatology of a region. The algorithms use very simple measures of the annual cycle of NLW and NSW. However, there are other parameters which are useful to distinguish between climatological types.

The area enclosed by the trajectory is one such parameter. Over temperate and boreal regions, the annual cycle retraces itself and the enclosed area is quite small. Over desert and steppe regions, the annual cycle moves around a large area in a counterclockwise direction, as though governed by a simple lag relation for the NLW. Over India, the annual cycle moves in a clockwise direction and the area is a large negative number. The fact that the area is negative emphasizes that the annual cycle is not driven by simple NLW varying with NSW with a lag, but by the monsoons. The slope of the annual cycle curve shows another aspect of the net longwave/net shortwave flux relation.

Precipitation is a very important component of climate. Although precipitation is not explicitly considered here, humidity and cloudiness are strong drivers of SRB components. Thus, regions of high/low precipitation have high/low cloudiness and humidity and concomitant low/high NLW.

Likewise, orography has a major influence on the climate of a region but is not explicitly considered here. The same considerations apply in regard to orography as for precipitation. Trenwarthe and Horne include highlands as a climatological type. In the present study, these regions appear as steppe. The Eurasian steppes are largely in the rain shadow of the Himalaya and Caucasus Mountains. In North and South America the regions which are classed as steppe are likewise in the rain shadow of the Rocky or Andes Mountains. The low humidity over these regions results in the NLW being large so that the regions are classified as steppe.

The interannual and decadal changes of SRB must have an effect on the boundaries between climatological types, both geographically and in terms of the parameters which are used by the algorithms presented here. These changes would depend on changes to Earth's hydrologic cycle readjusted by the movement of subsidence zones and changes of precipitation patterns, all of which are coupled with the SRB. In order to predict these changes, a model including biospheric, atmospheric and perhaps oceanic components is required.

The data used in this analysis is available from the Langley DAAC, at the website:
http://eosweb.larc.nasa.gov/project/srb/table_srb.html

4. CONCLUSIONS

A set of algorithms has been developed which classify the climate of a region based on the annual means and ranges of the surface net longwave and shortwave radiative fluxes. The resulting climate classifications compare quite well with other climate classifications based on other considerations. This correspondence between the SRB results with other classifications demonstrates the intimate relation between surface radiation budget and the climatology of a region. Changes in regional climate may analyzed using techniques as demonstrated here.

5. ACKNOWLEDGMENT

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6. REFERENCES

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